CONTRACT NO.: NAS5-32650
TASK NO.: 2103-347
SAI-ICD-028

EO-1 Spacecraft to Carbon-Carbon Radiator Interface Control Document (ICD)

SAI-ICD-028

SEPTEMBER 2, 1997

REVISION -

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1.0 SCOPE

This Interface Control Document (ICD) defines all interface requirements between New Millennium Program (NMP) technology item Carbon-Carbon Radiator and the Earth Orbiter-1 (EO-1) spacecraft. The ICD documents all interface-related agreements concluded between the technology provider and Swales Aerospace, the spacecraft contractor.

The purpose of this document is to specify the interface requirements in order to assure compatibility between the equipment furnished by the respective contractors. Changes to this document may be proposed by either party for formal approval by the EO-1 Project Office.

This ICD will serve as the controlling technical document between the Carbon-Carbon Radiator and the EO-1 Spacecraft. This ICD shall apply to all phases of Carbon-Carbon Radiator design, assembly, integration, test, launch and operations. This document is controlled by the Goddard Space Flight Center (GSFC) EO-1 project office.

2.0 APPLICABLE DOCUMENTS

The following documents of the exact issue shown form a part of the ICD to the extent specified herein. In the event of conflict between this ICD and the document referenced herein, the contents of this ICD shall be considered a superseding requirement.

2.1 APPLICABLE DOCUMENTS

SAI-STD-056	EO-1 Spacecraft Subsystem Allocations and Description
SAI-PLAN-138	EO-1 Contamination Control Plan
SAI-SPEC-158	EO-1 Verification Plan and Environmental Specification
SAI-PLAN-130	EO-1 Integration and Test Plan
SAI-QA-008	EO-1 Performance Assurance Requirements for S/C Bus
AM-149-0020(155)	System Level Electrical Requirements NMP EO-1 Flight, Litton Amecom
A0760	Carbon-Carbon Radiator Interface Control Drawing

3.0 INTERFACE REQUIREMENTS

3.1 INTERFACE DEFINITION

The Carbon-Carbon Radiator experiment is a honeycomb panel consisting of an aluminum core and Carbon-Carbon (C-C) face-sheets. Carbon-Carbon is a special class of composite materials in which both the reinforcing fibers and the matrix material is pure carbon. The use of high conductivity fibers in C-C fabrication yields a material that has both high strength and high thermal conductivity. Since its density is much lower than aluminum, significant weight savings can be realized with the replacement of aluminum panels and radiators with C-C. C-C also offers an advantage over other high conductivity composites, such as K1100/M55J because its thermal conductivity through the thickness of the material is much higher.

The current EO-1 baseline employs the use of radiators consisting of honeycomb aluminum panels. These are baseline as passive radiators with no heat pipes. The technology plan is to replace one of the S/C honeycomb radiator panels with a C-C panel. The aluminum panel that will be replaced measures approximately 28.62 inches by 28.25 inches. The panel will be used in a way that demonstration of the potential use of C-C technology for S/C radiators.

3.1.1 INTERFACE FUNCTIONS

The functions provided to the Carbon-Carbon Radiator by the Spacecraft, and conversely, are delineated in the following paragraphs.

3.1.1.1 <u>Spacecraft Interface Functions</u>
The following major interface functions shall be provided by the spacecraft.

a. Seven YSI 44900 series, part #GSFC-311-P-18, temperature sensors.

3.1.1.2 <u>Carbon-Carbon Radiator Interface Functions</u>
The following major interface functions shall be provided by the Carbon Space Radiator Partnership (CSRP).

a. Attachment interface for the Power System Electronics and associated hardware.
b. The C-C panel will be coated with a flight approved encapsulant such as epoxy to preclude any particulate generation that could be sensitive to the ALI.
c. Mounting interface for attaching the panel to the spacecraft.
d. Attachment interface for GSE handling.
e. Attachment for the LEISA Electronics and associated hardware.

3.2 <u>MECHANICAL INTERFACE REQUIREMENTS</u>

The Carbon-Carbon Radiator is mounted on the Bay #4 location of the spacecraft where the Power System Electronics and the LEISA/AC electronics are mounted. The Carbon-Carbon Radiator components are configured such that removal or repairs are possible while installed on the spacecraft. Threaded inserts shall be supplied on the interior of the panel for mounting the Power System Electronics at ten locations and the LEISA Electronics at four locations. Eight additional inserts shall be provided on the panel exterior for GSE handling of the integrated panel, as shown on drawing A0760.

3.2.1 CONFIGURATION

The dimensional drawings of the Carbon-Carbon Radiator is shown in drawing A0760. This includes mounting footprints, the location and orientation of the Power System Electronics, LEISA Electronics, and associated hardware.

3.2.1.1 <u>Coordinate System</u>
Orthogonal reference axes are established for the EO-1 spacecraft and the Carbon-Carbon Radiator. The Carbon-Carbon Radiator coordinate system is shown in drawing A0760.

3.2.1.2 <u>Configuration Drawings</u>
Reference drawing A0760.

3.2.1.3 <u>Field of View (FOV)</u>
The Carbon-Carbon Radiator shall be located in accordance with the following Field of View (FOV) requirements:

a. The Carbon-Carbon Radiator shall have a clear FOV to space.
b. The thermal radiating area of the Carbon-Carbon Radiator shall have a FOV as defined in the spacecraft thermal math model.

3.2.1.4 <u>Mounting Interface</u>
The Carbon-Carbon Radiator is mounted to the spacecraft at the 18 attachment points shown in drawing A0760. The PSE will be mounted at 10 attachment points and the LEISA Electronics will be mounted at 4 attachment points with #10-32 fasteners shown on A0760. Eight (8) additional ¼"-28 inserts will be provided on the external surface of the panel for GSE integration. The PSE, LEISA and GSE mounting inserts will be supplied by Swales. The inserts needed at the 18 attachment points for the spacecraft are the responsibility of the CSRP.

3.2.1.4.1 Flatness Specification
The mounting points on the spacecraft shall be flat within 0.01 inches (0.25mm).

3.2.1.4.2 In-Plane Accuracy
The mounting point centerlines shall be within 0.01 inches (0.25mm) from nominal.

3.2.1.4.3 Drill Template
Template will be provided by Swales to locate and drill the mounting interface to the spacecraft. The mounting interface for the PSE and LEISA/AC electronic boxes and GSE attachment points are defined in drawing A0760.

3.2.2 MASS PROPERTIES

3.2.2.1 Mass
The total mass of the Carbon-Carbon Radiator with all the necessary inserts for attaching to the spacecraft LEISA/AC and PSE shall not exceed 2.5 kgs. All changes in mass estimates, including expected growth, shall be reported promptly. The final Carbon-Carbon Radiator mass shall be measured to an accuracy of 0.1 kg.

3.2.2.2 Center of Gravity (CG)
The final Carbon-Carbon Radiator CG shall be measured to 5% accuracy.

3.2.2.3 Moment of Inertia (MOI)
The moment of inertia of the C-C Radiator shall be calculated with 5% accuracy.

3.2.3 MECHANICAL DESIGN and ANALYSIS REQUIREMENTS

3.2.3.1 Structural Design Safety Factors
All hardware shall be designed and analyzed to the applicable safety factors defined in Table 3.1. The analyses shall indicate a positive margin of safety.

All ground support handling hardware shall have a design factor of safety of 5 (ultimate loads) and test to a minimum factor of safety of 2 without any permanent deformation occurring.

Table 3.1

All flight hardware except pressure vessels	Test Qual
Material Yield Factors =	1.25
Material Ultimate Factors =	1.4

3.2.3.2 Limit Load Factors
The C-C panel shall be designed to withstand the quasi-static limit loads (with applicable safety factors) of ±15 g, in any direction. The panel shall be designed to support a PSE mass of 20 kg with a CG offset of 13.5 cm and a LEISA Electronics mass of 5 kgs with a C.G. offset of 11.5 cm from the panel surface.

In addition to above flight loads, the panel shall also be designed to sustain the following spacecraft loads while constrained at the S/C attachment points.

Shear Load of 16,100 N/m

Edge Normal load of 19,500 N/m

Panel Normal load of 1,850 N/m

The quasi-static limit loads and the S/C interface load cases will be considered simultaneously.

The maximum fastener forces at the S/C attachment points are given below:

Max tension force is 25 N

Max shear force normal to panel edge is 135 N

Max shear force parallel to panel edge is 115 N

The CC radiator panel must also be designed to react the on orbit thermally induced loads imposed on it by expansion and contraction of the S/C assuming temperature variations ranging from -20C to +60°C.

3.2.3.3 Structural Stiffness Requirement

In the launch configuration, the Carbon-Carbon Radiator shall have a first mode frequency greater than 100 Hz when hard mounted at the spacecraft attachment points with simulated masses for the subsystems.

A finite element model of the EO-1 satellite will be generated and used in the launch vehicle coupled loads analysis. To aid in this effort, the mass properties of the deliverable hardware will be required.

3.2.3.4 Stress Analysis Requirement

A stress analysis shall be performed to verify the integrity of the component structure and attachments when subjected to the specified loads with the applicable safety factors. Margins of safety shall be determined, dominant failure modes identified and this information transmitted to the satellite integrator. Existing mechanical stress analysis reports and data may be used if applicable.

3.2.3.5 Fastener Capacity

The deliverable hardware will be attached to the spacecraft panel using threaded fasteners supplied by Swales. Factor of safety shall be maintained for all the fasteners used on the spacecraft.

3.2.4 ALIGNMENT

No provisions shall be made for making alignment adjustments.

3.2.5 CARBON-CARBON RADIATOR HANDLING OPERATIONS and LIFT POINTS

3.2.5.1 Handling Operations

Normal care shall be exercised during handling and installation of the equipment. The GSE Handling fixtures attachment points are referenced in drawing A0760.

3.2.6 ACCESS REQUIREMENTS

3.2.7 EXTERNAL TEMPERATURE SENSOR MOUNTING

The spacecraft thermal engineer will specify the locations for mounting six interior temperature monitors on the C-C Radiator and/or PSE and LEISA/AC box and one external temperature monitor. Sensor locations (denoted with the letter “T”) are shown in Figure 3.1.

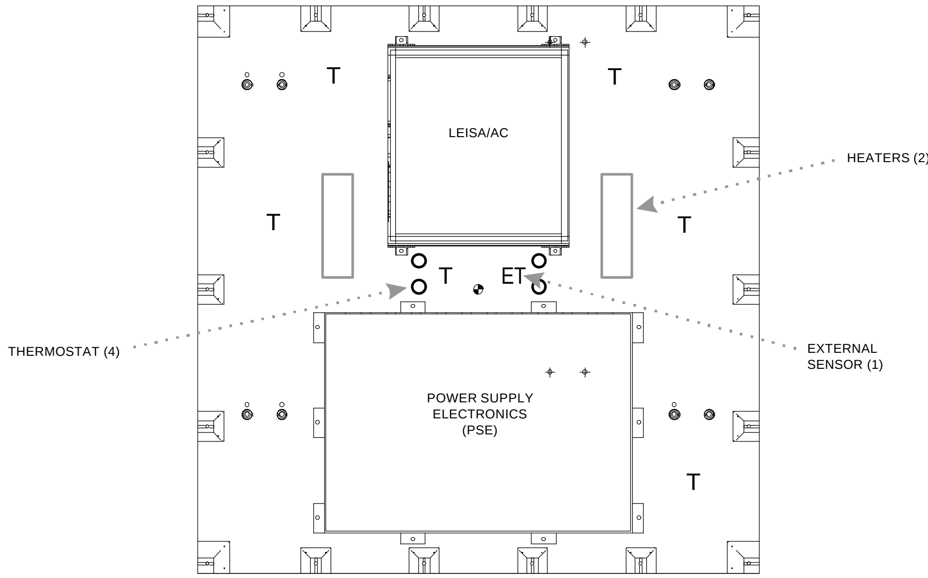

Figure 3.1 Temperature Sensor Mounting Locations

3.2.8 COVERS

No special covers are required.

3.2.9 NITROGEN PURGE

No purge is required.

3.2.10 THERMAL

The Carbon-Carbon Radiator shall be thermally coupled to the spacecraft.

3.2.10.1 Heat Flow Across the Interface

The attach point between the Carbon-Carbon Radiator and the spacecraft shall allow heat to transfer across the interface at a rate not less than 50 Btu/hr-sq. ft-°F (0.0284 W/sq. cm.-°K).

3.2.10.2 Heat Input to Carbon-Carbon Radiators

<u>Environment</u>:
The external environmental radiative heat flux on the Carbon-Carbon Radiator radiators shall be between 0 and 25 watts. The orbit average heat input from the Power System Electronics shall be 30-50 watts, and 0 - 10 watts from the LEISA/AC electronics.

<u>Heaters:</u>
Survival heaters will keep the PSE and LEISA/AC boxes at temperatures higher than 0°C.

3.2.10.3 Design Responsibility

The spacecraft thermal engineer is responsible for the thermal analysis of the combined Carbon-Carbon Radiator and spacecraft. The technology provider will supply a thermal design, analysis, and model to the spacecraft thermal engineer.

3.2.10.4 <u>Thermal Control Materials</u>

The technology provider is responsible for all thermal control materials for the Carbon-Carbon Radiator, except for thermal control blankets. The external C-C Radiator surface shall be silver teflon as specified in the spacecraft thermal math model.

3.2.10.5 <u>Thermal Testing</u>

The technology provider is responsible for performing a thermal vacuum test. There are four thermal cycles. Each thermal cycle contains a minimum 4 hour soak at + 50°C and - 10°C with heat dissipation to simulate the PSE and LEISA/AC electronics. A sufficient number of temperature monitors will be used during the test to verify the thermal design approach for the PSE and to test and verify the thermal performance of the C-C technology. The results will be documented in a test report and a copy provided to the spacecraft thermal engineer.

3.3 <u>ELECTRICAL INTERFACE REQUIREMENTS</u>

3.3.0 POWER REQUIREMENTS

None, other than temperature sensors and heaters.

3.3.1 COMMAND REQUIREMENTS

None.

3.3.2 GROUNDING

Common ground to spacecraft, as per System Level Electrical Requirements NMP EO-1, Litton Amecom document No. AM-149-0020(155).

3.3.3 TELEMETRY/DATA REQUIREMENTS

Seven YSI 44900 series, part #GSFC-311-P-18, temperature monitors. Data rate for each sensor will be at least one reading per minute per sensor, with 12 bit accuracy.

3.3.3.1 <u>Thermal Monitors</u>

The EO-1 spacecraft will provide seven thermal monitors and cabling to the monitors on or near several Carbon-Carbon Radiator assemblies to provide a gross measurement of the Carbon-Carbon Radiator thermal balance and, to provide a thermal measurement for EO-1 thermal balance. The mounting points are described in Section 3.2.7, the mechanical ICD section. Carbon-Carbon Radiator provides no interface other than providing mounting points for all temperature monitors. The EO-1 spacecraft will provide the temperature sensors and all cabling and conditioning. Any critical internal temperature monitors must be coordinated with the spacecraft integrator.

3.3.4 INTERFACE CONNECTORS and PIN ASSIGNMENTS

The interface connectors and pin assignments for the temperature sensors, heaters, thermostats, and grounding strap are shown in Table 3.2.

Table 3.2 Interface Connectors and Pin Assignments

Connector Type	Pin #	Function	Connector ID	From Box	From Connector
311P407-2S-B-12	1	Zone Htr 5A	TBD	ACDS C&DH/LVPC	P11
311P407-2S-B-12	2	Zone Htr 5A Rtn	TBD	ACDS C&DH/LVPC	P11
311P407-2S-B-12	3	Zone Htr 5B	TBD	ACDS C&DH/LVPC	P11
311P407-2S-B-12	4	Zone Htr 5B Rtn	TBD	ACDS C&DH/LVPC	P11
311P407-2S-B-12	5		TBD		
311P407-2S-B-12	6		TBD		
311P407-2S-B-12	7		TBD		

Connector Type	Pin #	Function	Connector ID	From Box	From Connector
311P407-2S-B-12	8	Bay 4 Temp	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	9	Bay 4 Temp Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	10		TBD		
311P407-2S-B-12	11		TBD		
311P407-2S-B-12	12		TBD		
311P407-2S-B-12	13		TBD		
311P407-2S-B-12	14		TBD		
311P407-2S-B-12	15	CC Temp 6	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	16	CC Temp 6 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	17	CC Temp 5	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	18	CC Temp 5 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	19	CC Temp 4	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	20	CC Temp 4 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	21	CC Temp 3	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	22	CC Temp 3 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	23	CC Temp 2	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	24	CC Temp 2 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	25	CC Temp 1 Rtn	TBD	ACDS C&DH/HK RSN	P36
311P407-2S-B-12	26	CC Temp 1 Rtn	TBD	ACDS C&DH/HK RSN	P36

3.3.5 ELECTROMAGNETIC COMPATIBILITY

Carbon-Carbon Radiator will not undergo EMC testing. All EMI/EMC testing will be done at the S/C level.

3.3.6 HARNESS

The S/C contractor shall provide harness for temperature monitors, heaters and thermostats.

3.4 ORDNANCE REQUIREMENTS

There are no electro-explosive devices used on the Carbon-Carbon Radiator.

3.5 RADIO FREQUENCY REQUIREMENTS

None.

3.6 ENVIRONMENTAL REQUIREMENTS

3.6.1 THERMAL

The Carbon-Carbon Radiator has no specific environmental restrictions.

4.0 DELIVERABLES

Item	From	To	Date
ICD Drawing	Swales	CSRP	1 July 97
C-C Panel Specs	Swales	CSRP	1 July 97
Drill Plate	Swales	CSRP	15 Dec 97
C-C Radiator	CSRP	GSFC	1 Jan 98
C-C Radiator	GSFC	Swales	31 Mar 98

5.0 SAFETY

The Carbon-Carbon Radiator presents no unusual safety hazards.